Transportation Energy

Énergie des transports

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

Canada

89-05374/

Prepared for:

Energy, Mines and Resources
Transportation Energy Branch
460 O'Connor Street
Ottawa, Ontario

Prepared by:

Applied Physics and Engineering Division
B.C. Research
3650 Wesbrook Mall
Vancouver, B.C.
V6S 2L2

April 1987

COMPRESSED NATURAL GAS HOME COMPRESSOR

OPERATIONS MONITORING

File No. 6-09-623

TE-87-8

DISCLAIMER

This study was carried out with the cooperation of the Department of Energy, Mines and Resources. However, the views expressed in the report are those of the author and do not necessarily reflect the views of the Department.

T4A/5238T

ABSTRACT

The operating performance characteristics of two CNG home compressors have been monitored over a thirteen month period. Operating data was collected for the total volume of natural gas used, total hours of operation, and electrical energy consumption. From this data, average flow rates were determined as well as the electrical energy consumption per unit of natural gas compressed.

TABLE OF CONTENTS

		Page
	ABSTRACT	i
	LIST OF FIGURES	iii
	LIST OF TABLES	iv
1.0	INTRODUCTION	1
2.0	DESCRIPTION OF THE HOME COMPRESSORS	2
	2.1 System Description of the RIX Home Compressor	2
	2.2 System Description of the I.I.E.C. Home Compressor	2
3.0	DESCRIPTION OF THE COMPRESSOR INSTALLATION	5
4.0	PERFORMANCE CHARACTERISTICS	9
5.0	PROBLEM AREAS ENCOUNTERED DURING THE MONITORING PROGRAM	14
6.0	CONCLUSIONS	14

LIST OF FIGURES

Figure	
1	The RIX Home Compressor
2	The I.I.E.C. Home Compressor
3	The I.I.E.C. Home Compressor

LIST OF TABLES

Table	
1	System Specifications for the RIX Home Compressor
2	System Specifications for the I.I.E.C. Home Compressor
3A	Operating Data for the RIX Home Compressor
3B	Operating Data for the RIX Home Compressor
4A	Operating Data for the I.I.E.C. Home Compressor
4B	Operating Data for the I.I.E.C. Home Compressor
5A	Problems Encountered During the Monitoring of the RIX Compressor
5B	Problems Encountered During the Monitoring of the RIX Compressor
6A	Problems Encountered During the Monitoring of the I.I.E.C. Compressor
6B	Problems Encountered During the Monitoring of the I.I.E.C. Compressor

COMPRESSED NATURAL GAS HOME COMPRESSOR OPERATIONS MONITORING

1.0 INTRODUCTION

The majority of natural gas vehicles presently operating in Canada are refuelled at multi-vehicle fuel stations featuring compressors that have flow rates of between 25 and 350 SCFM (standard cubic feet per minute). An alternative to this is the use of a small compressor that is installed at the home of the vehicle operator. Such a compressor would have a small flow rate of typically less than 5 SCFM. Refuelling of the natural gas vehicle could be accomplished by either a slow fill process (typically 4 - 8 hours) or by a fast fill, if a cascade refuelling system is used. The latter is far more convenient, however, the cost of the high pressure storage tanks makes this approach less attractive financially.

We have purchased, installed and monitored the performance of two home CNG compressors. They are:

1) RIX Industries HOM-GAS compressor (manufactured by RIX Industries San Francisco, California).

2) I.I.E.C. home compressor (originally manufactured by Outboard Marine Corporation, and now manufactured and distributed by Illinois Industrial Equipment Corp., Orland Park, Illinois).

This study had intended to monitor the performance of at least six home compressors. However, (when this study commenced) we found that there were only two companies that had commercially available compressors. In this report a brief description of each compressor will be presented. This will be followed by a summary of the monitoring operation and a discussion of the results. In addition, information on the problem areas encountered during this program will be given.

2.0 DESCRIPTION OF THE HOME COMPRESSORS

2.1 System Description of the RIX Home Compressor

The RIX HOM-GAS compressor is a small unit designed for filling receivers or pressure vessels in residential and commercial applications, including pressure vessels in automobiles and trucks that have been converted for natural gas operation.

The RIX compressor is shown in Figure 1. It is directly driven by an electric motor. A coupling on the other end of the motor is used to drive an oil pump for lubrication and cooling. The entire assembly is mounted to a steel flange and installed in a steel containment vessel to maintain explosion proof and leak proof integrity.

The compressor is a three stage, reciprocating pump using an axial piston drive. All bearings are open and are lubricated by the flow of oil cascading over the motor and compressor. The piston rings are a filled polytetrafluroethylene (PTFE) elastomer.

Pressure relief valves are located after each stage to prevent over-pressurization of the system. A fourth relief valve, which can be vented to an external standpipe, protects the containment vessel itself. A pressure switch shuts the unit down when the discharge gas pressure reaches the set point. A high temperature shutdown switch is provided as an additional safety feature. Lubrication and cooling is provided by a flowing oil system. A radiator mounted on top of the unit cools the oil. System specifications for the RIX home compressor are shown in Table 1.

2.2 System Description of the I.I.E.C. Home Compressor

The I.I.E.C. natural gas compressor is a three stage, air cooled, three cylinder conventional reciprocating pump in a semi-radial configuration. The unit is shown in Figures 2 & 3. The compressor consists of a belt

FIGURE 1

The RIX Home Compressor

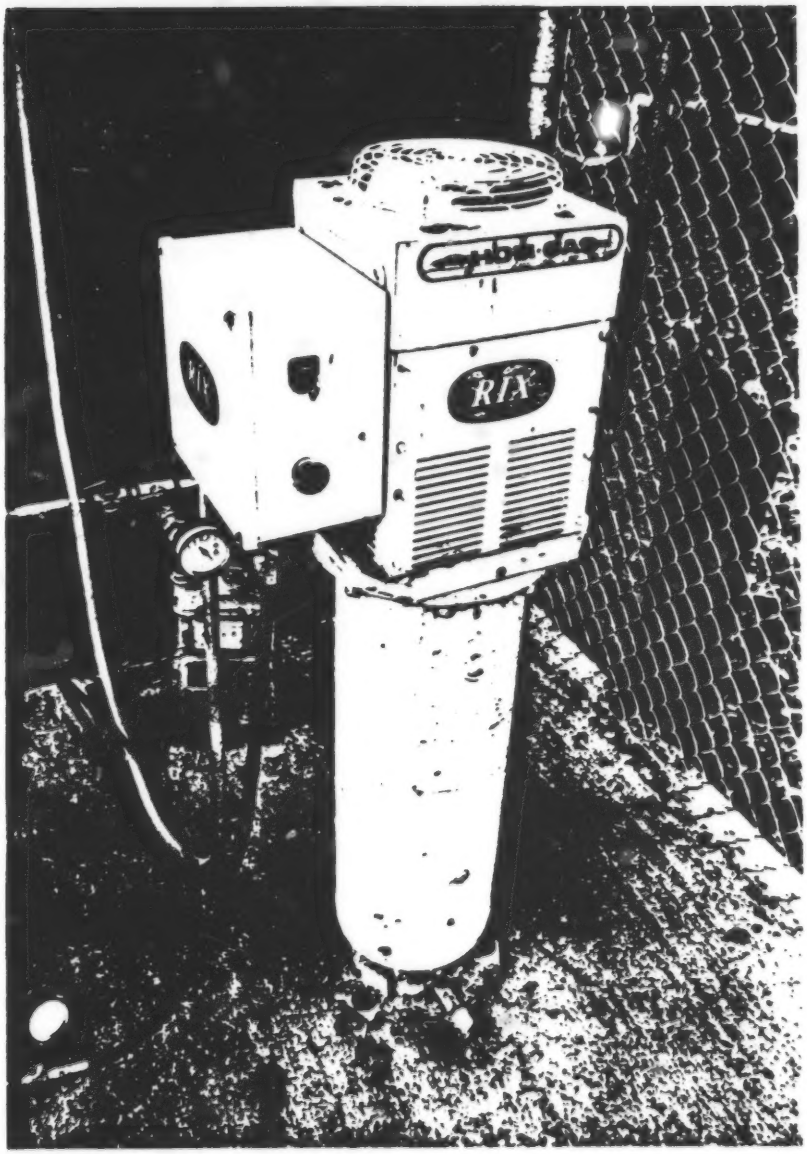

TABLE 1

System Specifications for the RIX Home Compressor

Descriptive Data	RIX Industries HOM-GAS Model, three state, axial piston, natural gas compressor package
Functional Characteristics & Rated Outputs relief valve setting)	Power required: 2.0 brake horsepower (2.0 HP electric motor) Pressure: 3000 psi maximum (standard Capacity: 2.0 Standard Cubic Feet per minute with 60 Hz power supply Speed: 1750 RPM @ 60 Hz or 1425 RPM @ 50 Hz
Environmental Characteristics	Designed to operate at ambient temperature of 50° to 125° and relative humidities to 100 percent. All external surfaces (except cooling fins) are plated or painted to resist corrosion. NOTE: Extra protection may be needed in marine or seriously corrosive environments.
Compressor Specifications	Piston Size: 1st Stage: 2.25" Dia. 2nd Stage: 1.00" Dia. 3rd Stage: 0.500" Dia. Stroke: 0.94" Cooling: Air/Oil Heat Exchanger Compressor Type: Oil Lubricated

driven pump, an electric drive motor, and the required plumbing and protection switches. The components are mounted on a steel chassis and are protected by a U-shaped steel cover.

Cooling of the compressor pump is provided by a fan which is driven off one end of the drive shaft. Lubrication is provided by a splash type oil bath. Pressure relief valves are located after each stage to prevent over-pressurization of the system. A pressure switch shuts the unit down when the discharge gas pressure reaches the set point. A high temperature shutdown switch is provided as an additional safety feature.

The system specifications for the I.I.E.C. compressor are shown in Table 2.

3.0 DESCRIPTION OF THE COMPRESSOR INSTALLATION AND MONITORING PROGRAM

The two home compressors monitored in this study were installed behind the BC Research natural gas refuelling station. The high pressure output from the compressors was fed into a cascade of twenty high pressure storage tanks which are used for the BC Research Ingersoll-Rand compressor (20 SCFM). When this compressor was not operating the small home compressors were used to fill the cascade.

Operating data was collected for approximately 13 months. This work is a continuation of earlier work also conducted at B.C. Research. The following data was collected for each compressor every two weeks:

1) Volume of Natural Gas Used
2) Hours of Operation
3) Electrical Energy Consumption

From this data the compressor flow rate and electrical energy consumption per unit volume of natural gas was determined.

FIGURE 2

The I.I.E.C. Home Compressor

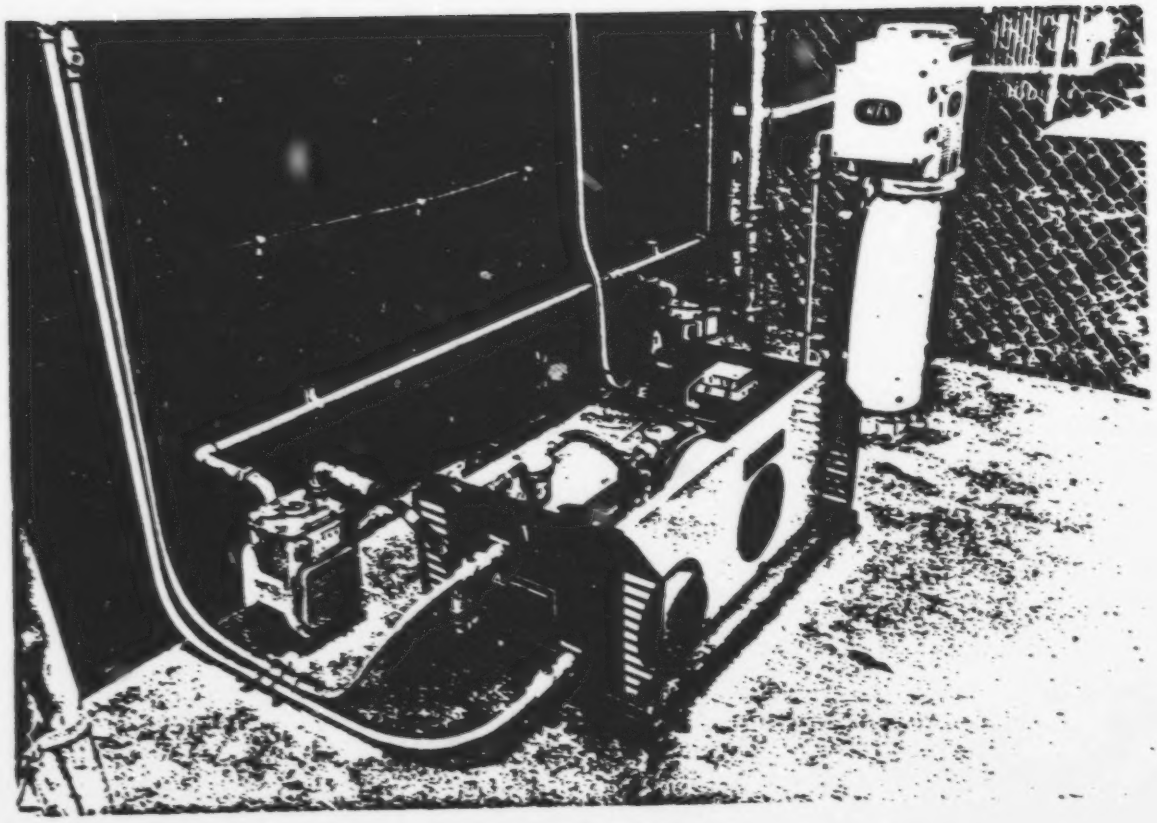

FIGURE 3

The I.I.E.C. Home Compressor

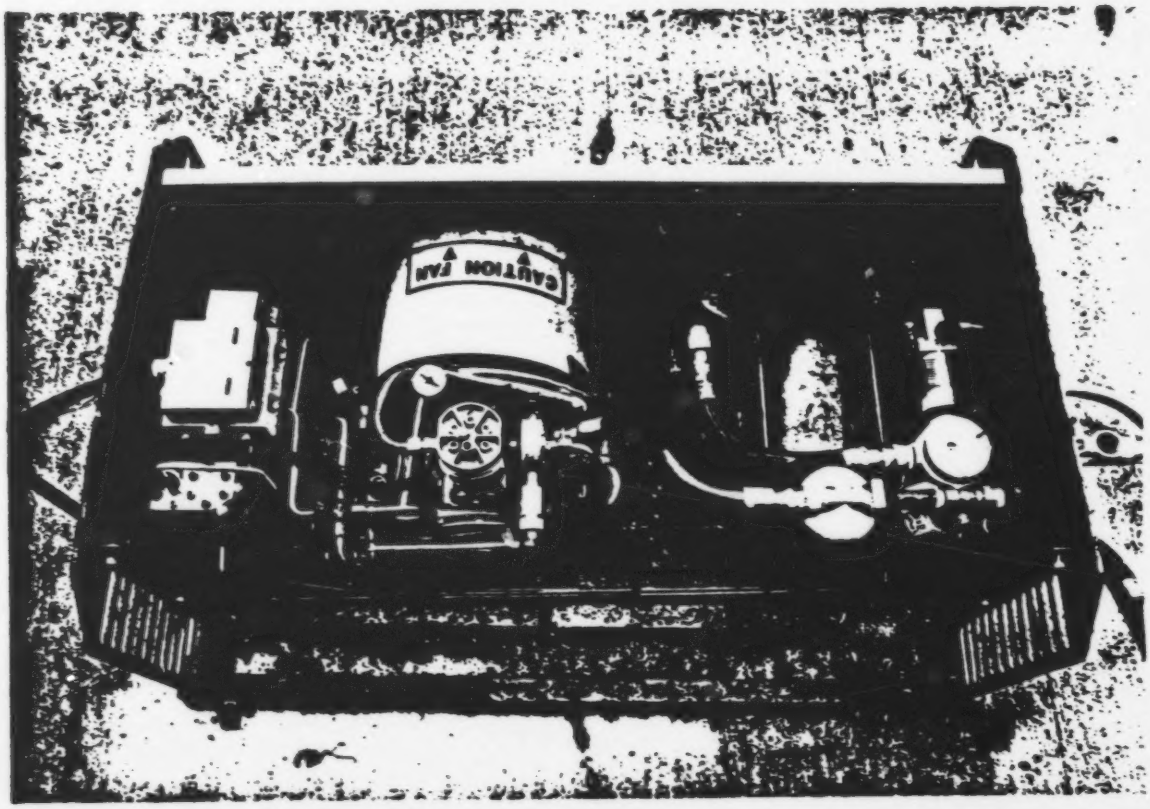

TABLE 2

System Specifications
for the I.I.E.C. Home Compressor

COMPRESSOR

Type ..... Reciprocating piston
No. of cylinders 3
No. of stages 3
Cylinder bore
1st stage ..... 2.362 in. (60 mm) dia.
2nd stage ..... 1.102 in. (28 mm) dia.
3rd stage ..... 0.472 in. (12 mm) dia.
Stroke ..... 0.945 in. (24 mm)
Output ..... 3 CFM (3600 cu. ft./24 hr day with 20 hr run time)

Working pressure
1st stage ..... 90 psig (6 bar)
2nd stage ..... 675 psig (45 bar)

Three different outlet pressures are available:
A. Time Fill ..... 2400 psi (160 bar)
B. Time Fill (Canada) .... 3000 psi (200 bar)
C. Fast Fill Compressor
used with Cascades ... 3600 psi (240 bar)

Sump and reservoir capacity ..... 40 oz (1183 cc)
Drive ..... 3 hp electric motor
Manufacturer ..... Bauer (built to I.I.E.C. specifications)
Speed ..... 2350 RPM

4.0 PERFORMANCE CHARACTERISTICS OF THE RIX AND I.I.E.C. COMPRESSORS

The performance characteristics of the two compressors are summarized in Tables 3B and 4B. During the period from February 25, 1986 to March 23, 1987 both compressors operated for approximately the same amount of time (the I.I.E.C. operated for 1035 hours and the RIX operated for 1037 hours). During this period the RIX compressed 2.08×10^3 cubic meters of natural gas while the I.I.E.C. compressed 4.92×10^3 cubic meters. The difference in volume of gas compressed is due to the flow capacity of the compressors.

The rated flow rate for the RIX is 0.056 m^3/min (2.0 SCFM) and 0.085 m^3/min (3.0 SCFM) for the I.I.E.C.. Both compressors did not operate at their maximum rated flow capacity during the period of the monitoring program. The average flow rate for the RIX was 0.033 m^3/min (1.18 SCFM) which is only 59% of the rated flow capacity. The average flow rate for the I.I.E.C. was 0.079 m^3/min (2.79 SCFM) which is approximately 93% of the rated flow capacity. Thus the I.I.E.C. compressor operated much closer to the manufacturer's claimed output flow than the RIX. The electrical energy required to compress unit volume of natural gas was also determined for both compressors. The I.I.E.C. was much more efficient in this regard than the RIX. The average energy consumption/unit volume is summarized below:

Average electrical energy consumption/m^3

	(kW-hr/m^3)
RIX	8.1×10^{-1}
I.I.E.C.	5.8×10^{-1}

TABLE 3A

Operating Data For The RIX Home Compressor

DATE	VOL (m^3)	ENER/VOL ($kW\text{-}Hr/m^3$)	HOURS	FL. RATE (SCFM)	FL. RATE (m^3/min)
Jul 09 84	$6.23 \times 10^{1}_{2}$	6.50×10^{-2}	27.0	1.36	0.04
Jul 23 84	1.84×10^{2}	5.19	77.5	1.40	0.04
Aug 07 84	2.35	5.14	103.0	1.34	0.04
Aug 20 84	4.25	6.69	181.6	1.38	0.04
Sep 04 84	3.51	4.84	287.0	0.72	0.02
Sep 17 84	6.97	4.66	342.5	1.20	0.03
Oct 01 84	7.02	4.66	345.1	1.20	0.03
Nov 13 84	7.05	4.66	345.5	1.20	0.03
Nov 26 84	8.01	4.68	378.3	1.25	0.04
Dec 10 84	8.78	4.71	417.3	1.24	0.04
Jan 21 85	1.10×10^{3}	4.77	511.5	1.27	0.04
Mar 04 85	1.27	4.82	602.9	1.24	0.04
Mar 18 85	1.35	4.84	653.0	1.22	0.03
Apr 02 85	1.40	4.84	672.8	1.23	0.03
Apr 29 85	1.47	4.84	684.5	1.26	0.04
May 21 85	1.55	4.84	716.6	1.27	0.04
Jun 03 85	1.73	4.82	779.3	1.31	0.04
Jun 24 85	1.94	4.80	861.0	1.33	0.04
Jul 08 85	2.01	4.79	886.8	1.33	0.04
Jul 22 85	2.12	4.78	925.0	1.35	0.04
Aug 07 85	2.14	4.77	930.1	1.35	0.04
Sep 03 85	2.16	4.77	937.5	1.35	0.04
Sep 16 85	2.16	4.77	938.3	1.36	0.04
Oct 15 85	2.38	4.77	1011.7	1.38	0.04
Dec 09 85	2.55	4.79	1073.7	1.40	0.04

TABLE 3B

Operating Data For The RIX Home Compressor

DATE	VOL (m^3)	ENER/VOL (kW-Hr/m^3)	HOURS	FL. RATE (SCFM)	FL. RATE (m^3/min)
Mar 17 86	2.81×10^3	4.78×10^{-2}	116.6	1.42	0.04
Apr 01 86	2.82	4.78	1163.7	1.43	0.04
Apr 14 86	2.82	4.78	1163.7	1.43	0.04
Apr 28 86	3.06	4.78	1243.1	1.45	0.04
May 12 86	3.20	4.77	1293.0	1.46	0.04
May 26 86	2.97	4.77	1307.4	1.33	0.04
Jul 02 86	3.42	4.75	1371.4	1.47	0.04
Jul 14 86	3.55	4.74	1424.2	1.47	0.04
Jul 28 86	3.67	4.73	1467.8	1.47	0.04
Aug 11 86	3.73	4.72	1492.7	1.47	0.04
Aug 25 86	3.93	4.71	1562.8	1.48	0.04
Sep 08 86	4.10	4.69	1621.3	1.49	0.04
Sep 22 86	4.18	4.71	1650.0	1.49	0.04
Oct 06 86	4.40	4.68	1731.6	1.49	0.04
Nov 03 86	4.91	1.68	1819.2	1.59	0.04
Nov 17 86	4.76	4.68	1855.5	1.51	0.04
Dec 01 86	4.86	4.68	1893.9	1.51	0.04
Dec 01 86	4.90	4.68	1907.8	1.51	0.04
Dec 05 86	4.96	4.69	1925.3	1.52	0.04
Feb 23 87	5.26	4.71	2016.4	1.54	0.04
Mar 13 87	5.46	4.72	2088.5	1.54	0.04
Mar 23 87	5.53	4.72	2111.0	1.54	0.04

TABLE 4A

Operating Data for the I.I.E.C. Home Compressor

DATE	VOL (m^3)	ENER/VOL ($kW\text{-}HR/m^3$)	HOURS	FL. RATE (SCFM)	FL. RATE (m^3/min)
Jul 09 84	2.75×10^2	7.68×10^{-2}	64.2	2.52	0.07
Jul 23 84	5.21	7.60	169.9	1.80	0.05
Aug 07 84	6.09	7.58	189.8	1.89	0.05
Sep 17 84	6.51	8.19	198.6	1.93	0.05
Oct 01 84	8.95	8.11	249.4	2.11	0.06
Oct 15 84	1.20×10^3	8.02	312.2	2.25	0.06
Oct 29 84	1.60	7.95	392.0	2.40	0.07
Nov 13 84	1.94	7.91	475.2	2.40	0.07
Nov 26 84	2.14	7.93	517.9	2.44	0.07
Dec 10 84	2.19	7.99	524.8	2.46	0.07
Dec 24 84	2.35	8.03	555.4	2.49	0.07
Jan 20 85	2.42	8.14	563.5	2.53	0.07
Feb 04 85	2.63	8.14	603.7	2.57	0.07
Feb 18 85	2.94	8.11	665.8	2.60	0.07
Mar 04 85	3.06	8.13	688.6	2.62	0.07
Mar 18 85	3.08	8.14	688.6	2.63	0.07
Apr 02 85	3.30	8.16	734.3	2.65	0.07
Apr 15 85	3.52	8.14	779.2	2.66	0.08
Apr 29 85	3.76	8.12	826.2	2.68	0.08
May 21 85	3.79	8.15	826.2	2.70	0.08
Jun 03 85	3.81	8.22	826.2	2.71	0.08
Jun 24 85	3.84	8.29	826.2	2.74	0.08
Jul 08 85	3.93	8.30	840.8	2.75	0.08
Jul 22 85	3.95	8.34	841.6	2.76	0.08
Aug 07 85	4.13	8.32	878.2	2.77	0.08
Aug 19 85	4.19	8.33	891.8	2.77	0.08
Sep 03 85	4.70	8.30	945.9	2.92	0.08
Sep 16 85	4.82	8.21	1031.1	2.75	0.08
Sep 30 85	5.15	8.16	1102.3	2.75	0.08
Oct 15 85	5.19	8.19	1108.0	2.76	0.08
Oct 28 85	5.47	8.15	1164.2	2.76	0.08
Dec 09 85	5.88	8.18	1239.5	2.79	0.08

TABLE 4B

Operating Data for the I.I.E.C. Home Compressor

DATE	VOL (m^3)	ENER/VOL ($kW\text{-}HR/m^3$)	HOURS	FL. RATE (SCFM)	FL. RATE (m^3/min)
Mar 17 86	5.88×10^3	8.18×10^{-2}	1239.5	2.79	0.08
Apr 01 86	6.19	8.19	1305.3	2.79	0.08
Apr 14 86	6.55	8.14	1383.6	2.79	0.08
Apr 28 86	6.57	8.17	1383.6	2.79	0.08
May 12 86	6.59	8.19	1383.6	2.80	0.08
May 26 86	6.61	8.21	1384.7	2.81	0.08
Jul 02 86	7.31	8.11	1597.2	2.69	0.08
Jul 14 86	7.57	8.08	1651.1	2.70	0.08
Jul 28 86	7.81	8.06	1697.3	2.71	0.08
Aug 11 86	8.24	8.02	1795.8	2.70	0.08
Aug 25 86	8.29	8.03	1801.8	2.71	0.08
Sep 08 86	8.31	8.05	1801.8	2.71	0.08
Sep 22 86	8.56	8.03	1851.5	2.72	0.08
Oct 06 86	8.58	8.05	1856.2	2.72	0.08
Nov 03 86	9.23	8.04	1920.5	2.83	0.08
Nov 17 86	9.11	8.04	1950.4	2.75	0.08
Dec 01 86	9.25	8.04	1979.5	2.75	0.08
Jan 05 87	9.85	8.01	2098.7	2.76	0.08
Jan 26 87	1.02×10^4	7.99	2172.6	2.77	0.08
Mar 23 87	1.08	7.99	2274.6	2.79	0.08

5.0 PROBLEM AREAS ENCOUNTERED DURING THE MONITORING PROGRAM

During the course of this monitoring program both compressors have been operated for more than 2000 hours. In general, for both compressors there have been no catastrophic problems encountered during this period. However, this is not to say that the compressors have been problem free. Each unit has experienced problems which would have prevented its operation for a home user. In Tables V and VI the major problems encountered for each compressor are briefly summarized. (It is clear from our operating experience that the reliability of these two compressors, if typical, needs to be significantly improved.)

6.0 CONCLUSIONS

Based on over 2000 hours of operating data there are a number of significant points that can be made which are summarized below regarding the performance characteristics of the two home compressors.

1) Both home compressors (RIX and I.I.E.C.) are capable of compressing natural gas to pressures of 3000 psi with flow rates of 0.033 m^3/min for the RIX and 0.079 m^3/min for the I.I.E.C.. The flow rate for the former is only 59% of the manufacturers rated output while the I.I.E.C. operated at 93% of rated capacity.

2) The efficiency of the compressor defined as the electrical energy/unit volume of natural gas compressed is slightly higher for the I.I.E.C. The average for the RIX was 8.1×10^{-1} kW-h/m^3, while it was 5.8×10^{-1} kW-h/m^3 for the I.I.E.C.

3) During the course of this monitoring program the major components of each compressor have been reliable. However, both compressors have been plagued by minor problems (e.g. leaks, electrical component failure) that have on a number of occasions resulted in a shut-down of the unit. This shut-down problem may not be acceptable for home operation.

TABLE 5A

Problems Encountered During the Monitoring of the RIX Home Compressor

Date	Hours	Problem
Jun 21 84	140.6	Cooling fan stopped operating.
Jun 26 84	140.6	Electric motor does not start when the starting key is switched on for the first few tries.
Aug 01 84	230.4	Cooling fan again stopped operating. The manufacturer is shipping a replacement part.
Aug 07 84	243.6	New fan motor is installed. Compressor motor still does not start on first few attempts.
Aug 17 84	322.6	Leak detected on the high pressure relief valve on top of the pressure vessel.
Sep 04 84	427.6	Compressor will not start. Fan still operational.
Dec 03 84	518.9	Added 500 ml of lubricating oil.
Jan 10 85	577.9	Water leakage inside the control box.
Feb 18 85	652.1	Compressor will not start.
Jul 05 85	1,031.2	Compressor requires 10-30 attempts to start in the morning, this has been a continual problem.
Nov 20 85	1,163.6	Compressor will not start, ambient temperature = -10°C.
Jan 29 86	1,202.3	Pressure vessel developed a leak.

TABLE 5B

Problems Encountered During the Monitoring of the RIX Home Compressor

Date	Hours	Problem
May 26 86	1,517.0	Starter motor relay failed. Replaced.
Dec 03 86	2,117.4	Removed inlet check valve (as instructed by Rix representative).
Dec 15 86	2,148.1	Compressor dismantled for inspection (as instructed by Rix representative). - moderate wear was measured in the second and third stage piston rod couplings (ball joints). - replaced old oil with a refrigerator type oil (Colpor 68) as instructed by the Rix representative.
Jan 07 87	2,148.1	Compressor would not start due to broken contact on starter capacitor and worn points on starter relay. Replaced starter capacitor.
Jan 08 87	2,148.3	Filed points and increased spring tension on the starter relay.
Jan 13 87	2,169.0	Continuous starting problem.
Jan 16 87	2,169.0	Starting motor overload tripping.
Jan 26 87	2,198.0	Compressor would not start at all.
Feb 10 87	2,198.1	Compressor dismantaled for inspection. - all wiring was checked for resistance and found wire number 5 to be broken. - a new wiring harness was made up and installed. - at the request of the Rix representative the factory starting relay was replaced by an electronic starting circuit.

TABLE 5B (con't)

Problems Encountered During the Monitoring of the RIX Home Compressor

Date	Hours	Problem
Feb 23 87		Compressor starting with no problems.

NOTE: Dennis Scott who represented RIX was first concerned about the low output of the compressor. We were requested to remove the inlet check valve. This did not change the output at all. He then was concerned about the starting problem and thought the oil we were using was too viscous for cold temperatures. After changing the oil to a new type, there was still a starting problem .

TABLE 6A

Problems Encountered During the Monitoring of the I.I.E.C. Home Compressor

Date	Hours	Problem
Jul 23 84	190.5	Relief valve between first and second stage is leaking.
Aug 20 84	210.4	Compressor is shut-down, awaiting relief valve.
Sep 04 84		Incorrect relief valve shipped.
Sep 10 84	212.2	Replaced relief valve. After 1 hr of running, an oil line worked itself loose. When unit was shut off for the day it speved condensate that appeared to be oil and water.
Sep 12 84	214.1	Ice was forming on the high pressure relief valve. Compressor vas shut off. After 3 minutes of running, valve was leaking.
Sep 17 84	219.2	Compressor vas shut down due to above problem. Second and third stage valves were dissassembled and inspected, all valves appeared to be operational. Unit reassembled, valve still leaks. A "statoseal" used around the locknut solved the problem.
Jan 24 85	592.4	Added 100 ml oil.
Apr 25 85	846.8	Added 140 ml oil.
Jun 24 85	846.8	Faulty oil pressure switch caused cyclic running.
Sep 03 85	966.5	Broken wire on high temperature switch prevented starting.

TABLE 6B

Problems Encountered During the Monitoring of the I.I.E.C. Home Compressor

Date	Hours	Problem
Feb 25 86	1359.9	Oil on compressor base. Gas smell detected while operating.
		- drained old oil (780 ml)
		- new oil added (1100 ml)
Apr 28 86	1504.0	- gas smell detected while operating (could not find source)
		- oil on compressor base (could not find source)
Jul 28 86	1817.7	- gas smell detected while operating (could not find source)
		- oil on compressor base (could not find source)
Sep 22 86	1971.9	- gas smell detected while operating (could not find source)
		- oil on base (could not find source)
Feb 02 87	2306.2	Detected gas leaking from vent pipe while operating (high pressure shutoff solenoid leaking - will replace)
Feb 05 87	2329.7	Removed compressor from housing for closer inspection
		- drained old oil (790 ml)
		- new oil added (1120 ml)
		- fan blade warped, one bearing worn, replaced fan blade.
Feb 06 87	2329.7	Checked bypass flow from crankcase, noted 18 SCFH (26 SCFH is maximum)
Feb 18 87	2392.7	Installed new high pressure shutoff solenoid, working properly.

TABLE 6B (con't)

Problems Encountered During the Monitoring of the I.I.E.C. Home Compressor

Date	Hours	Problem
Feb 23 87	2330.1	Detected gas leaking moderately on end of intercooler line leaking into third stage head. After closer inspection it was clear that the tube had been cracked for some time. The vessel and the end of the tube behind the nut remained siezed in the pipe/tube adapter on the third stage head.
Mar 13 87	2330.1	Replaced cooler/intercooler assembly. - gas leak detected under valve head cover tightened all head bolts, leak repaired.
Mar 23 87	2395.0	Noticed fan belt cracking. Replaced. - no gas smell detected - no oil on compressor base